SUSTAINING BIODIVERSITY CONSERVATION IN AND AROUND NYUNGWE NATIONAL PARK (NNP)

EVALUATION OF ENERGY-EFFICIENT IMPROVED COOKSTOVES (EES/ICS) DISTRIBUTION PROGRAMS NEAR RWANDA'S NYUNGWE NATIONAL PARK (NNP): HOUSEHOLD ATTRIBUTES, RATES OF USE, AND LEVELS OF SATISFACTION

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Prepared by Kel Rayens for the WildlifeConservation Society, May 2015.

I. Introduction to forest dependency and cookstove adoption worldwide

Forest dependency is of increasing concern as conservationists, economists, and social scientists research – with increasing urgency – the potential consequences of the relationships between deforestation, population growth, poverty, culture and technology. While forest dependency is an issue of tremendous global importance, it is particularly relevant in regions of the developing world that exhibit extreme levels of poverty but also house ecosystems that are incredibly rich in species number and diversity. It is no coincidence that areas of chronic rural poverty overlap with areas of rich natural forest: this is evidence of forest dependence for which there is no substitute (Sunderlin et al., 2005).

A great problem in the matter of forest dependency and deforestation is the issue of poverty. Poverty necessitates a focus on resource collection for the immediate future, depriving a region of the chance to invest in a sufficient land management plan for the long term. This lost time results in a gap in policy evolution, which fosters instability and uncertainty surrounding the future of that region's resource base. As a consequence, that region not only has severe day-to-day subsistence pressures, but also inadequate means for estimating how long those natural resources will be able to serve the growing population or whether they will be able to provide for any livelihood improvement. The available literature on forest dependency reveal such patterns of poverty and dependency across the world, particularly in Central and South America, Southern and Southeast Asia, and Africa.

As noted by Cordova et al. (2013) in their study in the western highlands of Guatemala, poor, developing regions often experience forest resource dependency that is heavy, steady, and very unlikely to decline in the foreseeable future. In their study, the poorest households were the most heavily dependent on forest products, but the wealthiest households had the highest rates of

forest use in absolute terms. This indicates a problem with equitable distribution of common pool resources.

Many intervention programs aimed at lessening forest dependence in the developing world focus on providing alternative fuel options. While it's a financially sound long-term idea (because of greater fuel efficiency), the high initial investment required for a switch to fuels like liquefied petroleum gas (LPG) makes it difficult for households to change to cleaner fuel sources (Israel, 2002; Babulo et al., 2008). Even more problematic is the widespread lack of market supply or geographic availability of alternate fuel types.

One notable theme in the literature on conservation policy is the importance placed on collaborative action: multiple approaches to poverty alleviation—not just centering on forest products – must be used in order to avoid overexploitation of forests (Fisher, 2004). A significant problem found by Walelign and Oystein (2013) in Mozambique is the lack of steady income through the year – livestock and business income were the only sources of earnings that didn't fluctuate significantly, and the harvest of forest products was essential to local households looking to make up the income difference when agricultural crop production was low. Logically, this dependence would be much more severe if crops failed unexpectedly, as there is so little income buffer available. Many studies suggest facilitating alternate wage-earning local economy (such as ecotourism) and promoting agroforestry to alleviate poverty and decrease pressures on forests (Masozera and Alavalapati, 2004; Walelign, 2013).

Promotion of ecotourism is an especially viable option in regions like sub-Saharan Africa, which is home to an immense amount of tropical diversity. This study focuses on Rwanda's Nyungwe National Park, which Plumptre et al. (2006) classify as a high-priority area for conservation in the Albertine Rift. The Rift is a large and dense region for biodiversity in Africa,

containing more endemic vertebrates than any other region of the mainland. However, the extreme human population density often frustrates or prohibits extensive efforts at habitat conservation. Large corridors and habitat buffers are necessary to support life for threatened migratory species, but corridor establishment is difficult because of the relatively unpredictable political relationships in this region of Africa, where population densities are high and political regimes of nations like the Democratic Republic of the Congo are historically volatile (Cordeiro et al., 2007).

To reconcile goals for conservation and poverty alleviation, payments for ecosystem services (PES) are increasingly popular in regions like Nyungwe. In an assessment of PES programs, Gross-Camp et al. (2012) found that equity in institutional and community involvement increases perception of legitimacy and positively influences participation in PES schemes. Within Rwanda, it is ideal to integrate PES systems with other community development plans, and to reduce transaction costs associated with participation in development schemes so as to increase numbers of households involved, thereby increasing policy effectiveness (Stainback and Masozera, 2010).

In examining possible collaborative plans, one technological option for decreasing forest dependency is to make a switch to energy efficient or improved cookstoves (ICS) in areas highly dependent on woody biomass for household fuel. Many studies have found that improved cookstoves have significantly greater fuel efficiency and lower pollutant emissions than traditional cookstoves or open fire hearths (Berrueta et al., 2008; Bhattacharya et al., 2002; Granderson et al., 2008; Jetter and Kariher, 2009). Improved cookstoves can be utilized as part of a profitable carbon trading scheme (Johnson et al., 2009) and can also produce biochar for use as a soil conditioner and beneficial agricultural input (Torres-Rojas et al., 2011).

The potential benefits of improved cooking technology are not limited to decreased fuelwood dependency, decreased deforestation, or poverty alleviation: more efficient cookstoves can have serious positive consequences on human health. 90% of smoke from open fire hearths is carbon monoxide, and, worldwide, half of the deaths that result from exposure to household fuel emissions are from severe pneumonia in children under 5 (Adler, 2010). There are many studies that find incidence and severity of respiratory illness is positively correlated with poor ventilation and exposure to indoor air pollution (IAP) from hearths and traditional cookstoves (Duflo et al., 2008; Ezzati and Kammen, 2001; Shen et al., 2009; Chapman et al., 2005). Women and children, because of their significant time spent in the house – particularly in traditional households most typically seen in poor, rural areas of the developing world – experience greater IAP exposure and resulting health problems. More research is needed to examine the effect of IAP on fertility, cancer, heart disease, weakening of the immune system, and a myriad of other potential negative effects on human health (Fullerton et al., 2008; Rehfuess et al., 2009; Clougherty, 2010). Exposure to IAP has also been linked to inhalation of dangerous toxins (An et al., 2007), high blood pressure (McCracken et al., 2007; Baumgartner et al., 2011), as well as headaches, back pain, and pain associated with the eyes (Diaz et al., 2007). Ezzati and Kammen (2002) outline an urgent need for research that would identify feasible and effective means of reducing exposure to IAP, now that the scientific community is soundly unanimous on its deleterious effect on human health.

While the benefits are many, researchers have noted some social and economic factors that can impede adoption of ICS. For example, within the traditional patriarchal household that is most typical of developing regions, there is a noticeable inequity between the person (generally a male head of household) who makes decisions regarding cooking technology and the persons

(generally women and children) who are greatest affected by the volume of the household's energy demands or the pollution that results from inefficient hearths (El Tayeb Muneer and Mukhtar Mohamed, 2003). In addition, there are a number of economic shortcomings associated with high initial investment costs (Edwards and Langpap, 2005; Hutton et al., 2007; Jeuland and Pattanayak, 2012) and commercial manufacturing operations that fail to directly benefit the local economy (Bailis et al., 2009). For these reasons, nearly all of the literature referenced so far in this review emphasizes a need for appropriate subsidies to accompany ICS adoption programs.

Lethargy in cookstove adoption has a great deal to do with limited education, low income and limited access to technology (Jan, 2012; Lewis and Pattanayak, 2012; Mobarak et al., 2012; Ruiz-Mercado et al., 2011), but the literature reveals possible adaptive tactics for improving cookstove adoption rates, including provision of subsidies and combination with other development plans for greater overall efficacy. Of foremost importance is ascertaining which variables most significantly affect households' decision on cookstove adoption. The next step is to craft policy that aptly addresses any impeding factors so as to encourage ICS adoption for the benefit of forest health and human health. There are very few studies of this kind in sub-Saharan Africa, which highlights the importance of this study in southwest Rwanda's Nyungwe region.

II. Background of ICS distribution near Nyungwe National Park

This survey and analysis evaluates rates of use and levels of satisfaction with ICS that were made available through two different distribution programs near NNP as described in the following paragraphs.

Distribution of Darfur stove types

Beginning in 2007, a partnership between the Wildlife Conservation Society of Rwanda (WCS), Partners in Conservation (PIC), and the Rwandan government (specifically the Rwandan Defence Forces, or RDF), constructed and distributed 2300 stoves within Bweyeye sector of Rusizi district. The ICS distributed is the Darfur stove type, pictured here:

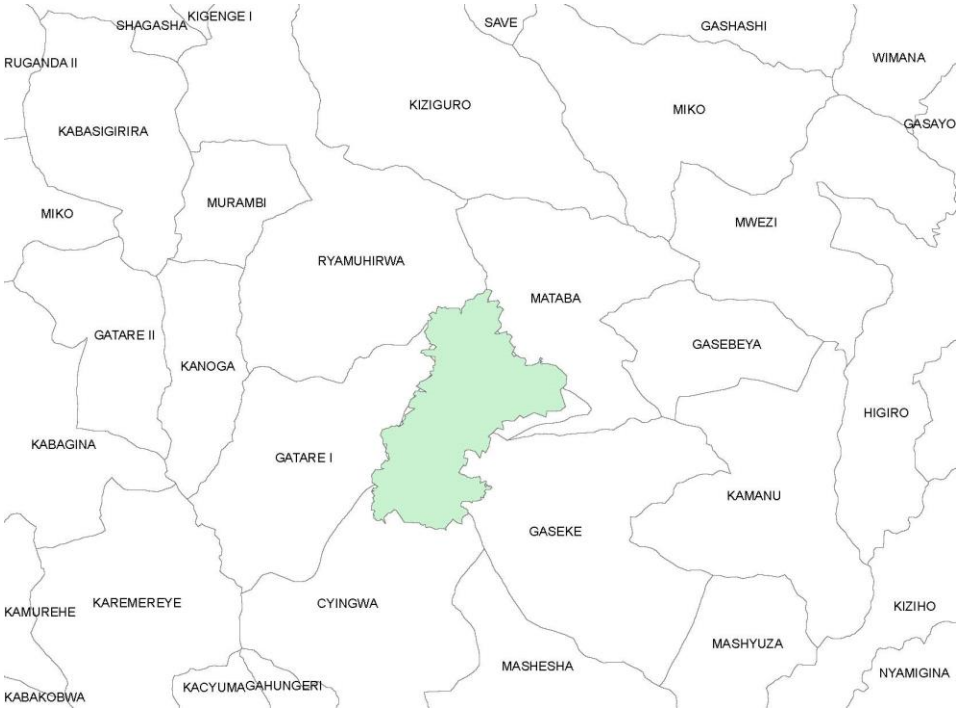
2300 Darfur stoves were distributed in Rasano, Gikungu, Murwa, Nyamuzi and Kiyabo, which are all administrative cells of Bweyeye sector.

Distribution of canarumwe stove types

In 2012, a partnership between the Wildlife Conservation Society of Rwanda (WCS), and national NGO Rural Environment and Development Organization (REDO) distributed 100

stoves within each of the Nkungu and Bweyeye sectors of Rusizi district. The ICS distributed is the *canarumwe* stove type, pictured here:

100 *canarumwe* stoves were distributed throughout Kiyabo and Gikungu – two administrative cells in Bweyeye sector -- and 100 stoves were distributed in the Gatare cell of Nkungu sector. Maps of sectors and cells are shown below:



The Nkungu and Bweyeye sectors were chosen for ICS distribution in part because they are directly adjacent to Nyungwe National Park (NNP) and thus could have the greatest positive effect on decreasing illicit forest product harvest and habitat disruption within NNP. The Bweyeye cells of Nyamuzi, Gikungu and Kiyabo are wedged directly between NNP and the border with Burundi. The Nkungu cells of Gatare and Mataba directly border Cyamudongo, 4 square kilometers of biodiverse forest that is part of the greater NNP region and houses Rwanda's only habituated chimpanzee population.

III. Survey purpose and development

The purpose of the survey is to provide feedback to those government and non-governmental organizations exploring promotion and adoption of ICS on a regional or national scale in Rwanda. There are no existing evaluations of cookstove adoption programs in Rwanda and the

resulting use frequencies and user satisfaction. This report serves as a reference for other researchers and organizations looking to conduct evaluations of ICS programs and cookstove use and satisfaction generally, whether in Rwanda or in other countries with similarities in social, economic or geographic characteristics.

The survey was organized into three primary sections: *Household characteristics*; *Household cooking and fuel*; and *Improved cookstove perception and satisfaction*. The finalized survey template is attached at the end of this document, in English and in Kinyarwanda. Of particular interest to the researchers is which socioeconomic attributes of households have significant effect on frequency of ICS use and user satisfaction with the ICS. In light of this, the results highlight relationships between dependent-variable use frequencies and independent variables such as household size, income category, gender of the head of household, land ownership, livestock value, or number of children in the household.

IV. Survey implementation

Enumerator training took place on June 18, 2014 and survey administration (conducted through in-person interview) began on June 23, 2014. There were two enumerators, one for Bweyeye and one for Nkungu. From each sector administration center, we obtained a list of households that had been part of these two ICS programs: Nkungu and Bweyeye were both part of the 2012 *canarumwe* program, and additionally Bweyeye had been part of the 2007 *Darfur* program.

From each list of ICS program participants, we selected a simple random sample of 50 primary respondents using random number generation. We then randomly selected an additional

10 respondents from each list that would function as alternates, should enumerators find that a respondent from the primary list of 50 had moved away or could not be located.

In summary, we included 150 respondents that had been part of an ICS program at some point: 50 *canarumwe* recipients in Nkungu (Gatare cell), 50 *canarumwe* recipients in Bweyeye (Nyamuzi, Gikungu and Kiyabo cells), and 50 *Darfur* stove recipients in Bweyeye (Nyamuzi, Gikungu and Kiyabo cells). To mitigate overlap and double-counting, respondents in Bweyeye who had been part of both the *canarumwe* and *Darfur* programs were listed singly and never appeared on both lists.

Lastly, each sector administrative office provided us with complete resident listings for the applicable cells within that sector. From this list, we selected a simple random sample of households that had not participated in either of these ICS programs. In Bweyeye, 50 households (plus 10 alternates) were chosen from Nyamuzi, Gikungu and Kiyabo; in Nkungu, 50 households (plus 10 alternates) were chosen from Gatare and Mataba.

Summary of targeted respondent selection via SRS

	Bweyeye	Nkungu
Non-recipients	50	50
Canarumwe recipients	50	50
Darfur stove recipients	50	

V. Results and discussion

1. Summary of respondent household characteristics across sectors

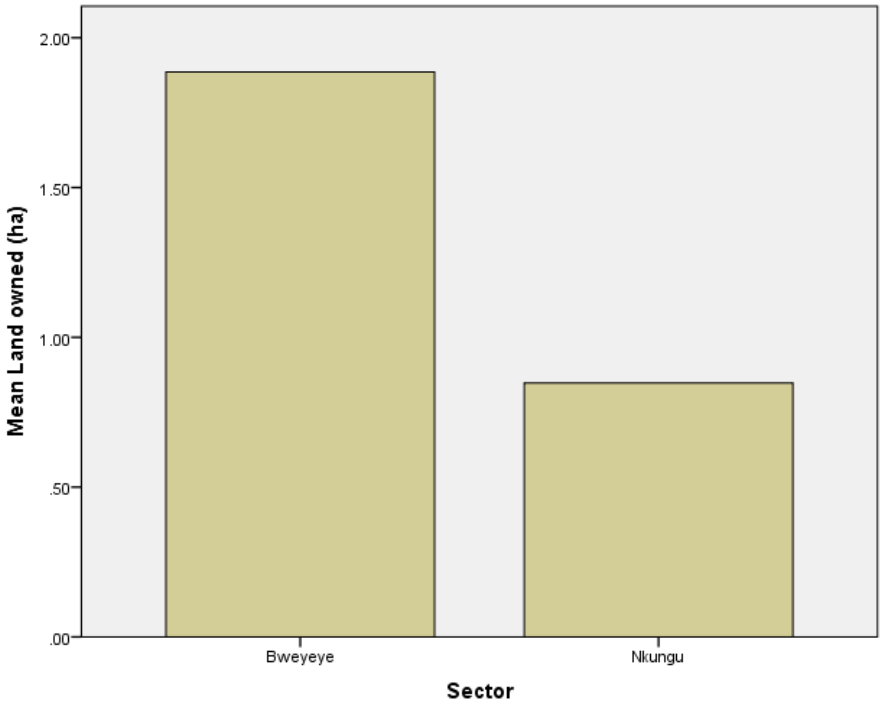
To begin, we look first at the averages of household characteristics across the range of respondents in both Bweyeye and Nkungu. Land holdings range from 0 to 5 hectares (ha), with an average of 1.47 ha across all 250 valid respondents. Average livestock value per household is 186,000 RwF (271 USD). The average size of a privately owned woodlot is 0.20 ha. On average, households contain 5.73 total members and 2.59 children. These complete findings are summarized in the table below; averages are seen in bold:

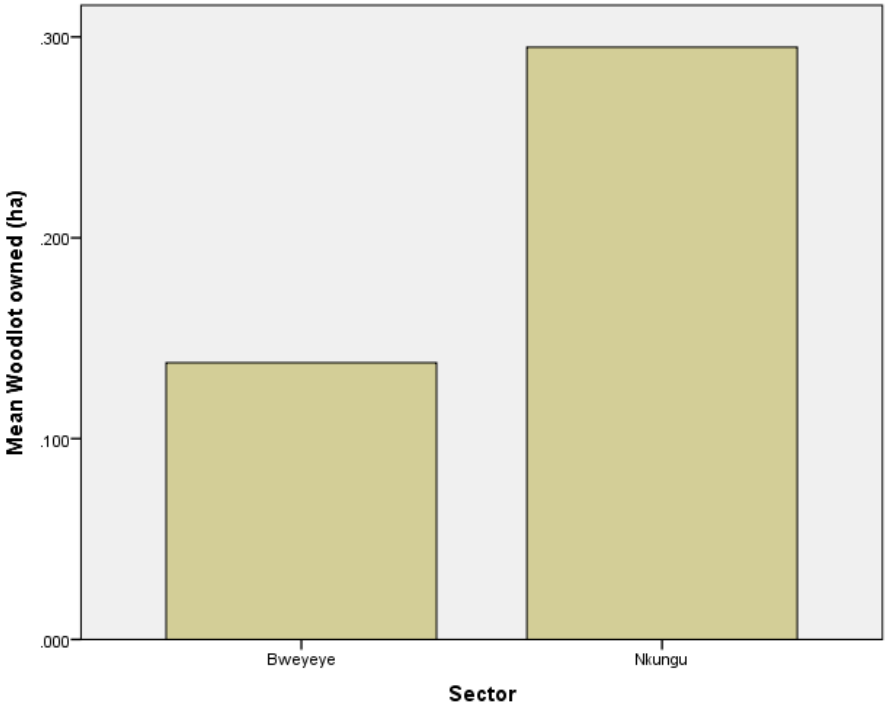
Descriptive Statistics

	N	Minimum	Maximum	**Mean**	Std. Deviation
Land owned (ha)	250	.00	5.00	**1.4746**	1.14713
HH combined annual off-farm income	14	10000	1600000	553285.71	462688.203
Total HH livestock value (RwF)	246	0	1394000	186713.41	232684.121
Total HH livestock value (USD)	246	0	2028	**271.58**	338.450
Woodlot owned (ha)	242	.000	5.000	**0.19820**	.495826
# of HH members	251	1	12	**5.73**	2.285
Number of children in HH (ages 1-15)	241	0	8	**2.59**	1.749
Valid N (listwise)	12				

A large majority of households (70.4%) fall into income category 3, which lies in the middle of the 1-5 scale defined by the Rwandan government and recorded by the census. An additional 18.2% of respondents fall into income category 2, and the remaining 11.4% are distributed in the relative extremes of income classification. Within our sample only 16.1% of households have a female head of house.

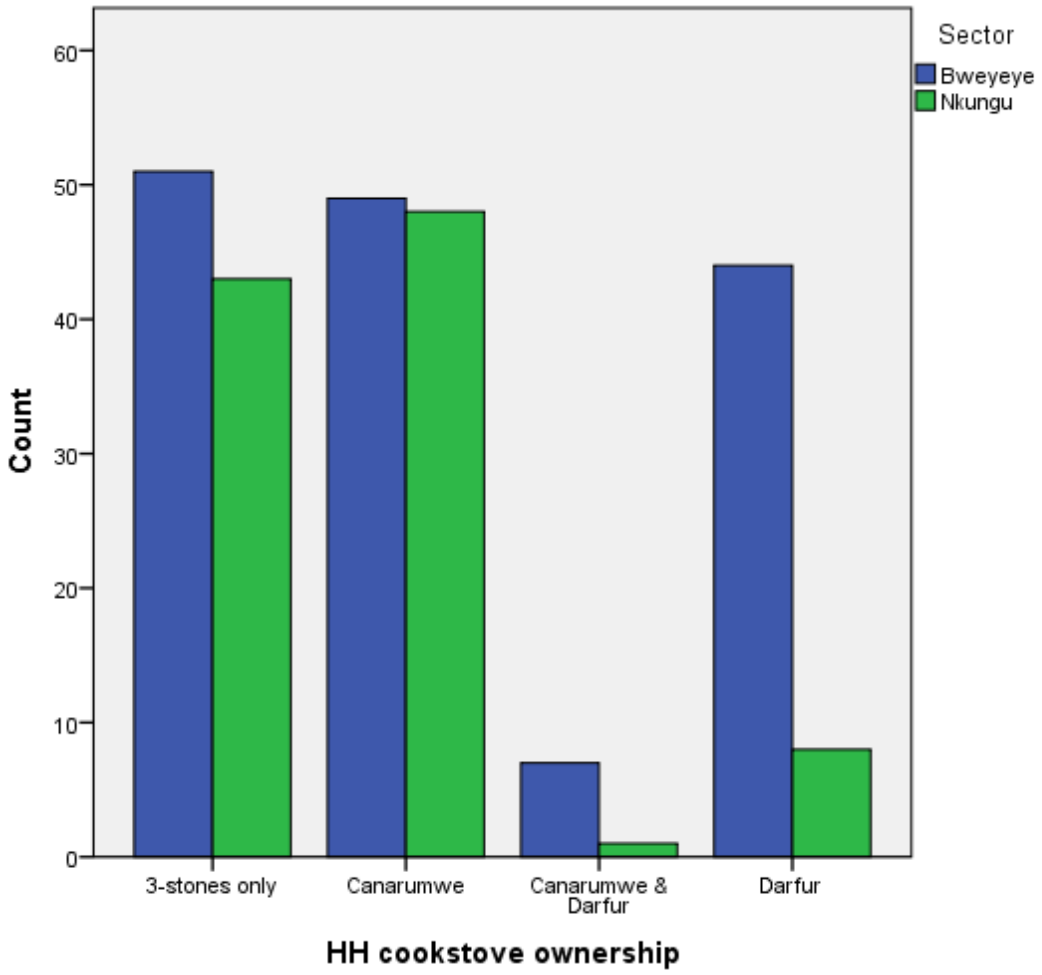
Overall, both sectors were fairly uniform with respect to household characteristics – major exceptions arose only with regard to land and woodlot ownership, as illustrated below.





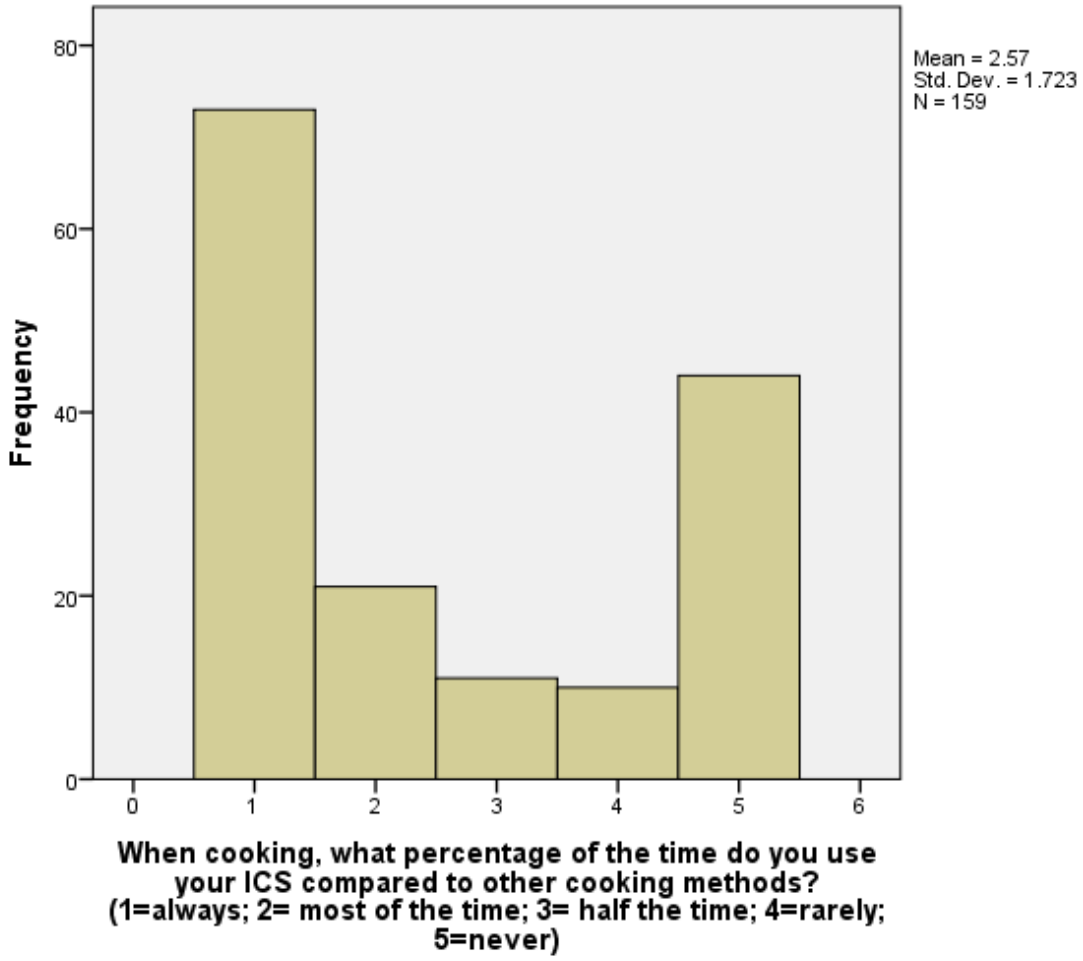
2. Cookstove ownership and rates of use

In examining cookstove ownership, the below graph represents types of improved cookstoves owned by households in both sectors:

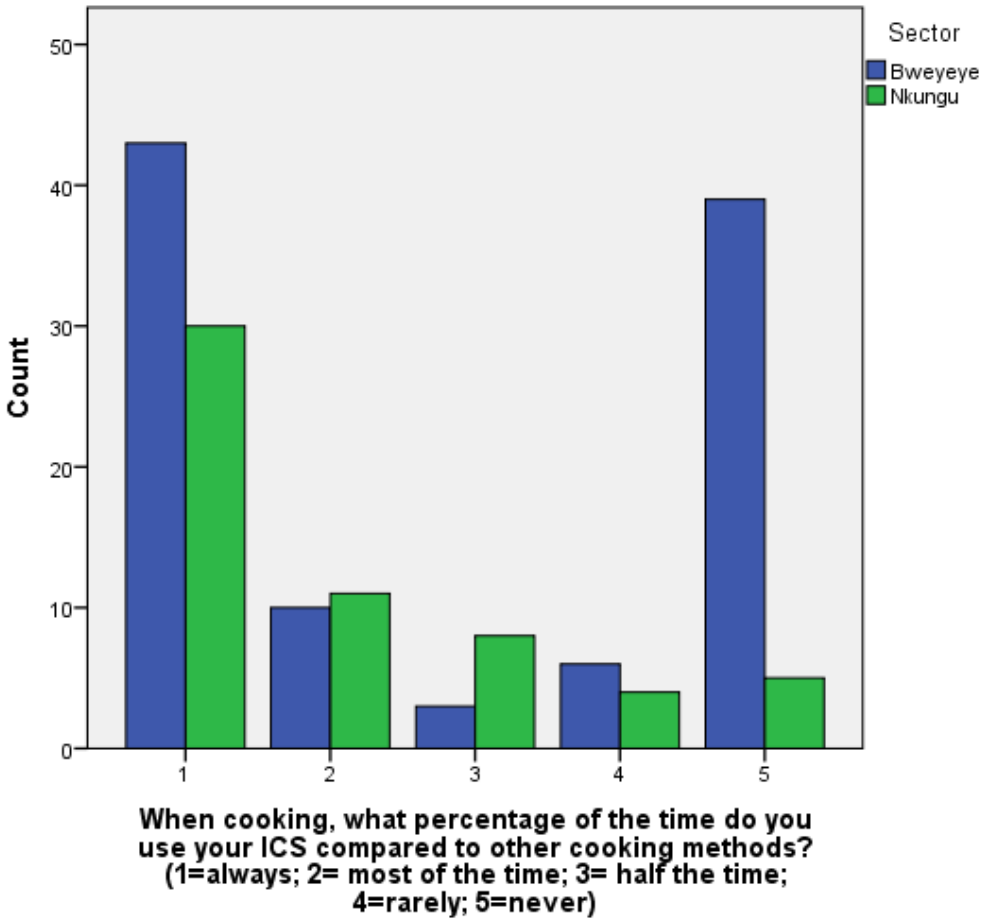


Because of our sampling method, the above representations are not surprising, although Nkungu residents did apparently have some level of access to *Darfur* stoves even if the 2007 program did not take place there. Please note that, in the above graph, ownership of an ICS does not imply sole use of that ICS; in many cases, households used an ICS (or sometimes two) in conjunction with a traditional 3-stones stove. Because of this, and to understand use frequencies, the survey inquired about how cookstove types are used. The below graph represents the

frequency of stove use among those households that had ever received or purchased an ICS. The results for this component of the survey are very interesting:



Nearly half of respondents report always using their ICS compared to other cooking methods, but many also report not using it at all – and in fact, for many of these households the ICS did not show up on the map of the kitchen (drawn by our enumerators during the interviews) as even being installed in that household. When the data are divided by sector, this is the result:



When examining the difference in use between ICS types, the reason for this very significant difference between sectors becomes clear. Rates of use among *Darfur* stove recipients (Bweyeye residents, as described in the methodology) are highly polarized: **32 out of 52 *Darfur* stove recipients (61.5%) report *never using it*.** The complete distribution is outlined in Table 1.

Table 1: Rates of use for *Darfur* stove recipients (n=52)

	Number of households	Percent of households
Always	15	28.8
Most of the time	3	5.8
Rarely	2	3.8
Never	32	**61.5**

In contrast, the average rate of use of the *canarumwe* stoves is quite high. Of all 96 canarumwe recipients, across both sectors, only 11 households (11.4%) report never using the stove. **48 out of 96 households (50.0%) report *always* using the *canarumwe*.** The complete distribution is outlined in Table 2.

Table 2: Rates of use for *canarumwe* stove recipients (n=96)

	Number of households	Percent of households
Always	48	**50.0**
Most of the time	28	29.2
Rarely	9	9.4
Never	11	11.4

The vast difference in cookstove use frequencies between stove types is not immediately understandable from our available numerical survey data. Because the rates of use for *Darfur* recipients is so low, we examined translated portions of the open-ended responses that were included in those surveys.

Some households had not provided enough information in the open-ended answers to be included in this analysis, but in total 38 surveys of *Darfur* recipients were examined in order to create the tabulated information seen below. When respondents were asked to comment on their stove's performance, responses fell within three categories: 1. The stove is satisfactory and still in use; 2. The stove performed well but then broke (often within a time frame viewed as excessively short by the user); and 3. The stove was destroyed with the grass-thatched house. Results are presented in Table 3.

Table 3: Comments from *Darfur* stove recipients on the stove's performance (n=38)		
Darfur stove still in use	*Darfur* stove broke	*Darfur* stove destroyed with the grass-thatched house
8 (*21.0%*)	17 (*44.7%*)	13 (*34.2%*)

These results help to explain much of the anomaly seen in rates of use for the *Darfur* cohort. For the significant majority of *Darfur* recipients (in this sample, nearly 80%), the rate of use can only be "Never", because the stove no longer exists in the home. These respondents are *Darfur recipients* but no longer *Darfur owners*.

There are two important components of the discussion that stems from these data. Firstly, it does appear that the design, construction or installation of the Darfur stoves is unsatisfactory based on its relative fragility for the user. Because this survey did not explore daily use patterns and methods for individual households, we cannot make direct assumptions about the cause of the failure of these Darfur stoves. It is possible that the stove design was not strong, or that recipients were not using the stoves with the ideal installation configuration or support. However, it is clear that the functionality and use of the stoves is certainly limited for the Bweyeye residents.

Secondly, there appears to be a housing policy change that resulted in significant loss of these stoves for Bweyeye residents. Thirteen out of 38 respondents stated that their stoves were destroyed along with their grass-thatched homes. We are unsure of the exact policy associated with this housing change, but it has had a significant effect on the use rates of ICS in this sector. Consultation with RDB or other government bodies should help elucidate those policy details and the effect that they had.

3. Fuelwood use between ICS and non-ICS households

Of particular importance in the evaluation of these ICS/EES programs is the effect that improved cookstove technology can have on decreasing fuelwood consumption. Energy efficient stoves can reduce fuel needs, which can translate into decreased pressure on private wood lots, the buffer zone, and the NNP.

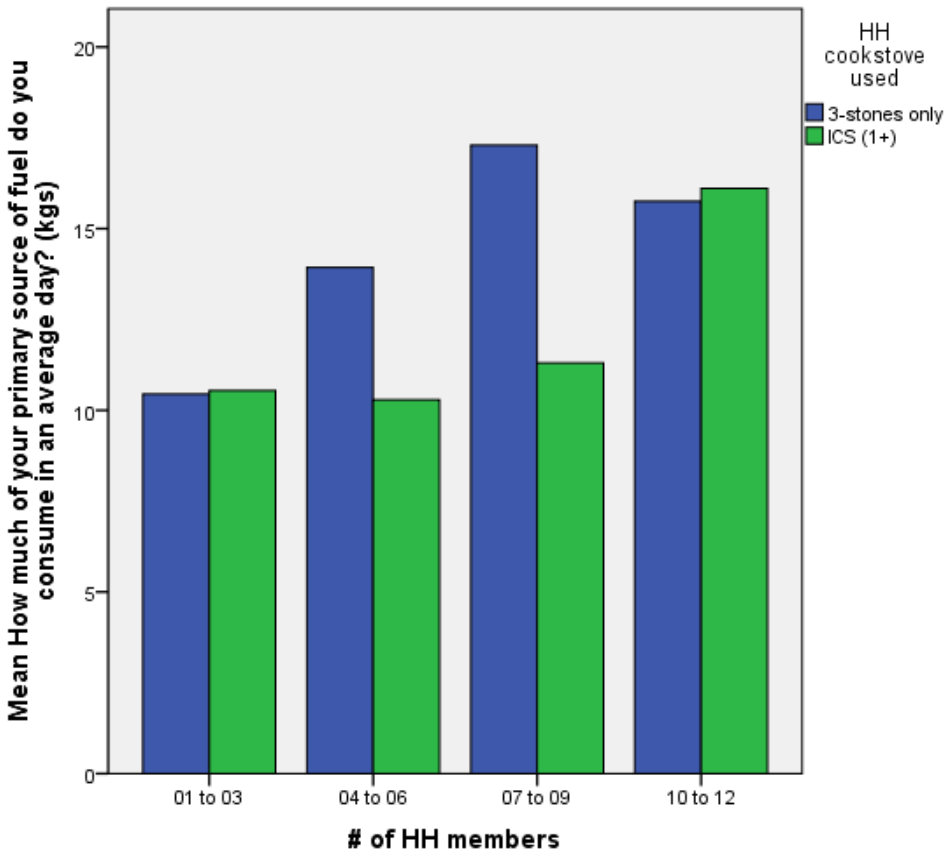
This survey asked participant households to self-report their average daily fuelwood use in kilograms. Out of the 236 households (across both sectors) that provided information on wood consumption, the average amount fuelwood consumed per person per day is 2.62 kgs. This is consistent with the finding of Gross-Camp et al. (2015), who surveyed 78 households in cells adjacent to the NNP and found that the amount of wood collected per person per day ranged from 1.05 to 7.52 kgs. Across all cells, their sample population averaged 2.78 kgs of wood collected per person per day (GC et al., 2015), a figure comparable to our 2.62 kgs. We include this comparison to establish continuity with previous related studies in the Nyungwe region.

Out of the 236 households that reported fuelwood consumption, 113 of those are ICS users and 123 households use only 3-stones stoves. When we compare wood use between these groups, the difference is stark. The median fuelwood consumption (per person per day) for ICS users is 1.67 kgs. For those households using only 3-stones stoves, the median is 2.83 kgs. *NB: For this calculation, the aforementioned Darfur stove recipients who reported never using the ICS – and who had only a 3-stones stove installed in the household – were included with the other households using a 3-stones stove only.* The summary of the medians and interquartile ranges are presented in Table 4, on the following page:

Table 4: Measures of spread in fuelwood consumption across ICS and non-ICS households (*kgs per person per day*)		
	Households using only 3-stones stoves (n = 123)	Households using at least one ICS (n = 113)
Median	2.83	1.67
Q1 (25%)	1.88	1.00
Q3 (75%)	3.75	2.43
Interquartile range	1.87	1.43

Median values are preferred for this comparison, as the mean value is inflated by a few single-person households with very high fuelwood consumption (it is possible that these few households are operating as restaurants, but that information was not explicitly asked in our survey). Rather than discard outliers, we chose to use the nonparametric Mann-Whitney U test to accommodate the skewness of the data. The distributions in the two groups differed significantly (Mann-Whitney U = 28.2450, $p < 0.0001$). Use of an ICS in the household has a definitive effect on fuelwood consumption, reducing the median consumption value by more than a kilogram per person per day. We consider this reduction in fuel consumption to be a conservative estimate, as some households continued to use a 3-stones stove in conjunction with their ICS; for these households we were not able to parse the fuel consumption for the different stove types.

When examined across household size, the ICS potential to reduce fuel use appears to most positively benefit households of a medium-to-large size, as seen in the following graph.



The lack of positive effect on reduced fuel use for very small or very large families could be due to a variety of factors, but it should be noted that 193 of our 251 total households fell into the "4 to 6" and "7 to 9" categories of household size. At the extremes, the fuelwood consumption results from the smallest and largest household size categories are more susceptible to outliers that may skew the result.

4. Cookstove ownership and health effects

The last section of the survey that this report discusses are the self-reported health statistics from households. This information is presented as a general narrative rather than as statistically significant, because many households did not report health information but it was not clear whether they did not choose to complete that section or the survey or whether they did not have any health events to report.

In total, 142 out of 252 households provided information on 1 or more health events as described in section 1.4 of the survey. Table 4 displays these results:

Table 4: Incidence of ailments across 142 households

Headache	Sore eyes	Coughing	Shortness of breath	Wheezing	Dizziness
153	60	66	20	22	33

When divided between ICS users and 3-stones users, there are no observable differences in the frequency or kind of health ailment experienced by household members. There are several reasons that this might be the case, including an insufficient length of time in allowing ICS use to have a positive effect on respiratory health since these particular stoves have only been in use over the past few years. However, as our health data from this survey were not complete, we suggest a more detailed and tailored health survey to be conducted with both ICS and 3-stones stove users in Rwanda.

VI. Summary of major findings

In conclusion, this survey and analysis finds that fuelwood usage for ICS/EES users in Bweyeye and Nkungu is significantly less than their counterpart 3-stones users (section V.3). Our analysis also found that rate of use for *Darfur* stove recipients is significantly lower than for *canarumwe* owners (section V.2), and much of this is due to the *Darfur* stoves having broken during household use or having been destroyed along with grass-thatched homes that seem to have been razed as part of a national or regional housing policy change.

This survey has been the first of its kind in Rwanda, and offers invaluable insights into the implementation and success of ICS/EES adoption programs. There is a clear reduction in wood consumption for those households using an improved stove, and if the challenges of stove design and, in this case, conflicting housing policy can be overcome, the overall fuelwood dependence for Rwandan households could decrease significantly. That benefit can accrue to Nyungwe National Park, Rwanda's protected areas, and to rural communities and their ecosystems.

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